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AVIONICS SYSTEMS ENGINEERING DIVISION INTERNAL NOTE

77

MAIN PROPULSION FUNCTIONAL PATH ANALYSIS FOR PERFORMANCE MONITORING FAULT DETECTION AND ANNUNCIATION

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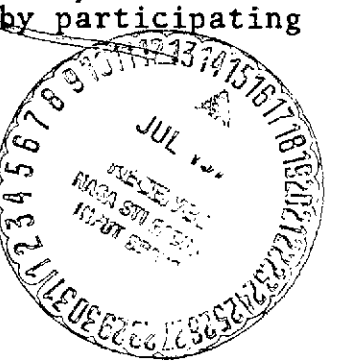

National Aeronautics and Space Administration

LYNDON B. JOHNSON SPACE CENTER

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MAIN PROPULSION FUNCTIONAL PATH ANALYSIS FOR PERFORMANCE MONITORING FAULT DETECTION AND ANNUNCIATION

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ABBREVIATIONS

Disc	Disconnect
E	Engine
Eng	Engine
GH_2	Gaseous Hydrogen
GO_2	Gaseous Oxygen
He	Helium
HPFT	High Pressure Fuel Turbine
HPFTP	High Pressure Fuel Turbo Pump
HPOT	High Pressure Oxidizer Turbine
HPOTP	High Pressure Oxidizer Turbo Pump
LH_2	Liquid Hydrogen
LO_2	Liquid Oxygen
ME	Main Engine
OX	Oxidizer
PNEU	Pneumatic
Reg	Regulator
RPM	Revolutions Per Minute
RSV	Relief Shut-off Valve
SOV	Shut-off Valve

1.0 SUMMARY

A total of 48 operational flight instrumentation measurements have been identified for use in performance monitoring and fault detection. Thirty of these measurements are contained in Volume I of the Master Measurements List.

The Operational Flight Instrumentation List, from the main propulsion panel meeting, November 28, 1973, contains all measurements identified for fault detection and annunciation. It is recommended that these measurements be included in the next revision of the Master Measurements List.

In addition, 16 controller data words have been identified for use in fault detection and annunciation. Eight of these data words are not presently in the first 32 data words which will be available to performance monitoring. It is understood that the data word list is being revised to relocate these words.

2.0 MAIN PROPULSION SYSTEM

2.1 Description

The main propulsion system consists of the following:

- External Tank
- Orbiter Plumbing
- Main Engine (three each)
- Main Engine Controller (three each)
- Operational Flight Instrumentation

2.1.1 External tank. The external tank houses propellant for the main engine and provides the structural interface for the launch configuration.

2.1.2 Orbiter plumbing. The Orbiter plumbing provides flow paths and controls for propellant transfer from the external tank to the main engine.

2.1.3 Main engines. The three main engines are reusable hydrogen fuel cooled liquid propellant rocket engines with variable thrust and mixture ratio. Each engine operates at a mixture ratio (liquid oxygen/liquid hydrogen) of 6 to 1, and a chamber pressure of approximately 3000 psia to produce a sea-level thrust of 375,000 pounds and a vacuum thrust of 470,000 pounds. The engines are throttlable over a range of 50 to 109 percent of design thrust level. This provides for high-thrust level during liftoff and early ascent and allows limiting Orbiter acceleration to 3 G's during final ascent. The engines are gimbaled to provide Thrust Vector Control.

2.1.4 Main engine controller. Each main engine has a dedicated controller (DCU) which interfaces commands and data between the vehicle and the engine. Main engine fault detection is also provided by the controller.

The controller consists of two identical, independent, stored program, general-purpose, digital computers, each having a self-contained random access memory, arithmetic/control section, and power supply. Each computer has a 16K, 17 bit word, memory capacity.

One controller channel will be active for control. The second channel will be in a monitor mode ready to take the active role on controller command if the active channel fails.

2.1.5 Operational Flight Instrumentation (OFI). Volume I of the Shuttle Master Measurements List, dated November 16, 1973, defines the instrumentation presently baselined for the Main Propulsion System.

3.0 FUNCTIONAL PATH ANALYSIS

Figures 1 through 8 identify the functional paths of the external tank and Orbiter plumbing of the Main Propulsion System. They are identified to be consistent with the identification used by Rockwell International as defined in Rockwell International internal letter 392-RGM-73-037; dated August 31, 1973; subject, "Documentation of Subsystem Functional Path Analysis."

These functional paths are defined at the component level and identified MEXXX or METX. Various combinations of these functional paths are used together during different mission phases as operating functional paths. The operating functional paths used for performance monitoring during flight are identified OMEXX.

3.1 Functional Paths

3.1.1 Main Engine No. 1. Figure 1 defines the functional paths for Main Engine No. 1 helium supply. Figures 2 and 3 define the paths for Main Engines 2 and 3.

ME 1 is a quick-disconnect check valve used for connecting the helium fill manifold to a ground loading source. The check valve serves as a backup for the four source bottle valves.

ME 2 is a 4.5 cu. ft. helium holding source for Main Engine No. 1. The source pressure is maintained at a pressure of 4000 to 4200 psig and a temperature of 500 to 580° R by a ground source until liftoff minus 30 seconds.

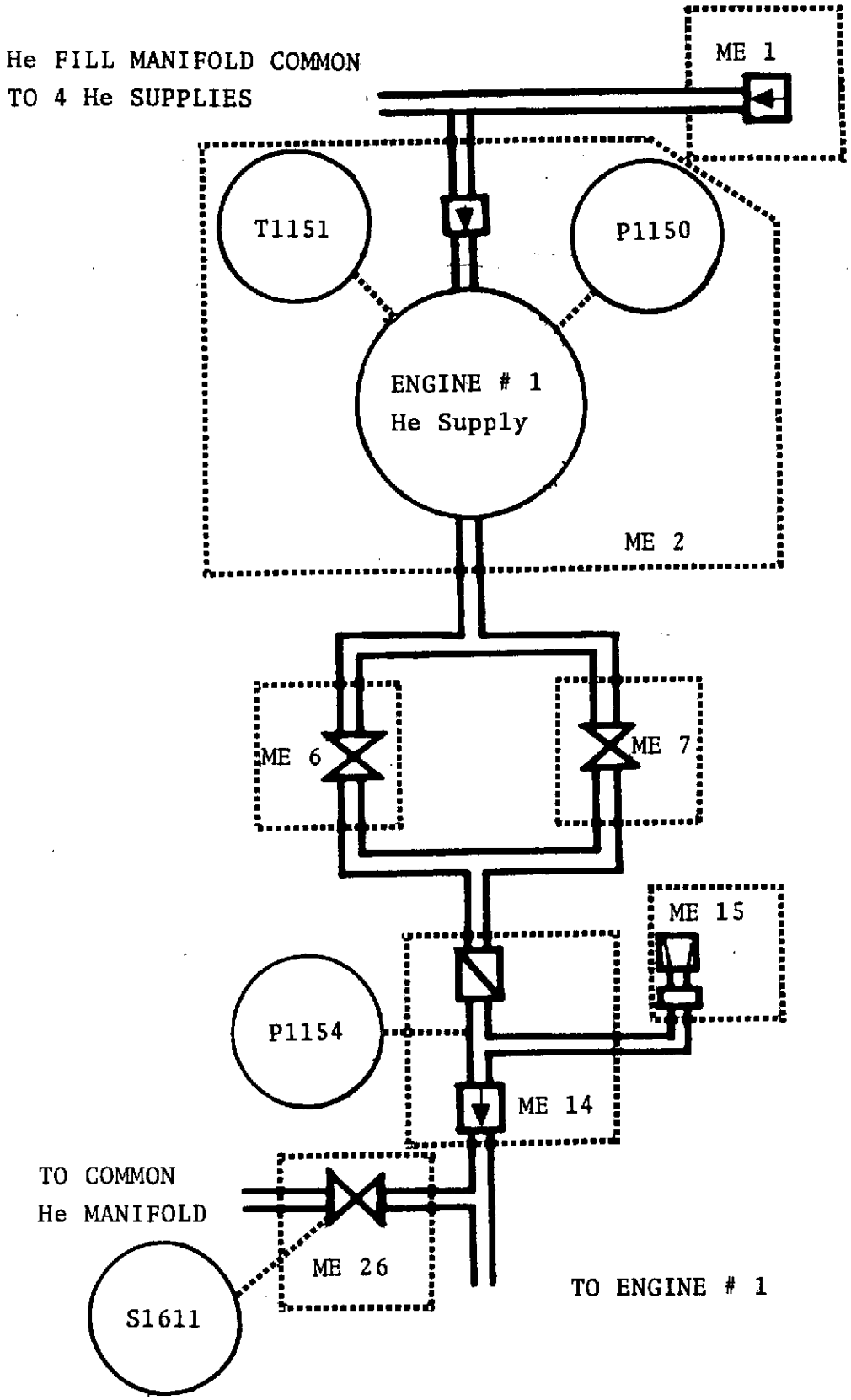

Figure 1. – Engine No. 1 – He supply functional paths.

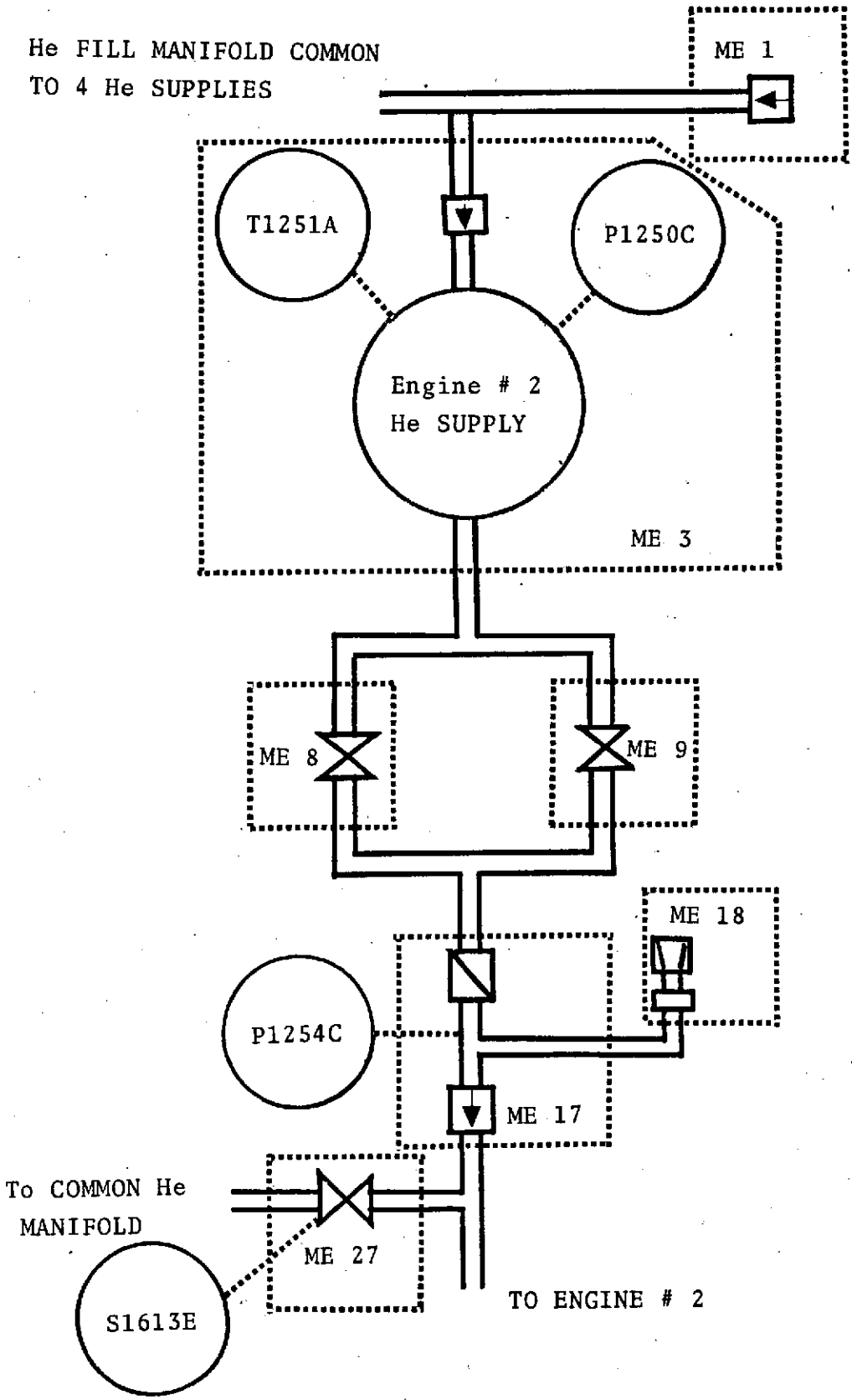

Figure 2. — Engine No. 2 — He supply functional path.

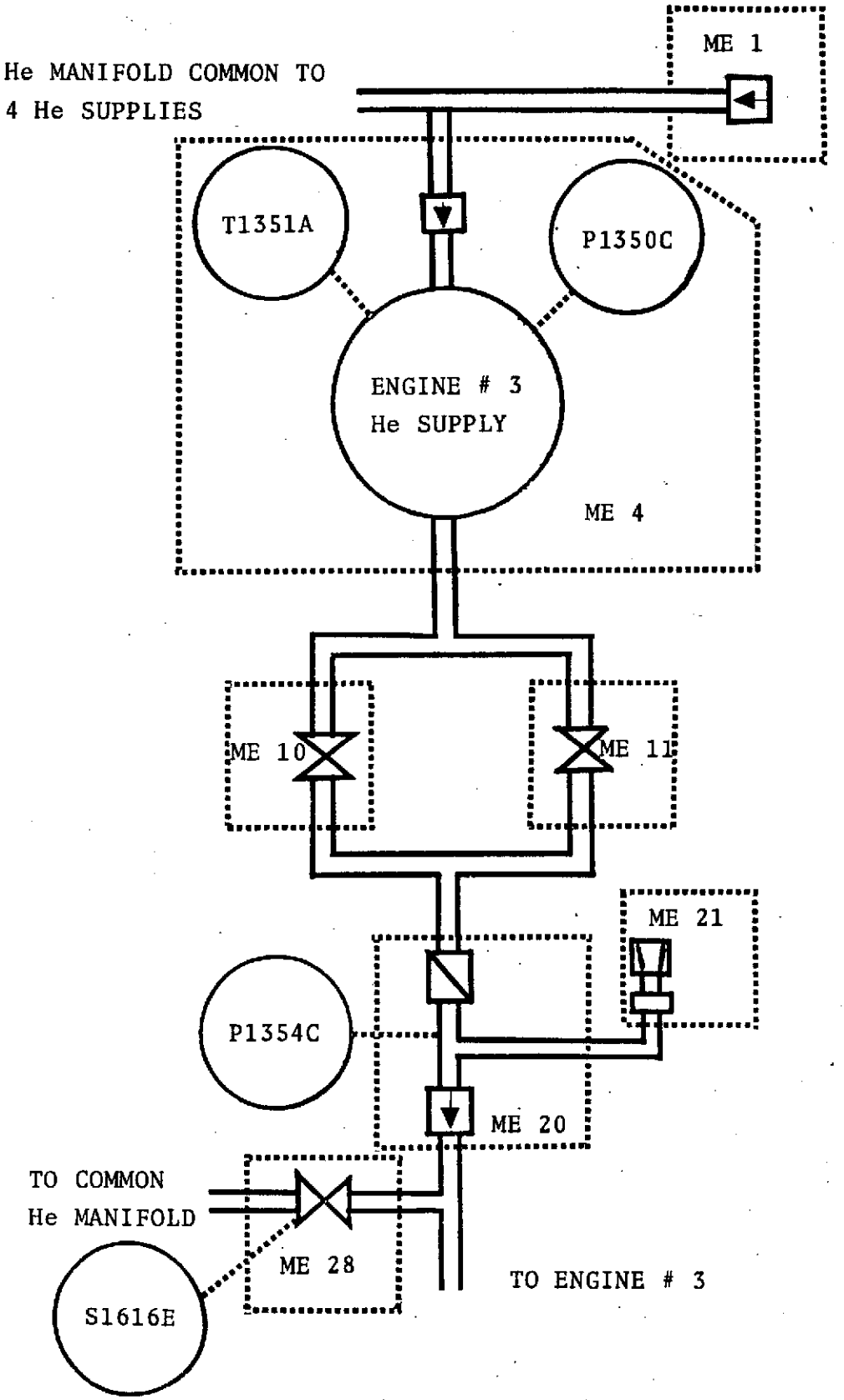

Figure 3. – Engine No. 3 – He supply functional paths.

ME 6 and ME 7 are helium shut-off valves used to isolate the helium source from the engine flow path. Both valves are commanded open by the engine controller just prior to engine start.

The regulator in ME 14 regulates the helium source pressure to engine purge pressure, 750 ± 35 psig. The check valve prevents back flow to the helium source in the event the engine is being supplied from a different source through ME 26.

ME 15 is a burst disc and poppet relief valve to protect the engine from excessive pressure in the event the regulator in ME 14 fails open.

ME 26 is a shut-off valve that connects engine 1 to a helium manifold normally supplied by the pneumatic helium supply, source bottle No. 4. In the event ME 26 is opened, ME 6 and ME 7 are closed.

Helium is used by the engine during burns to purge the cavity between the high-pressure oxidizer turbo pump turbine seals. Approximately 20 psig in the helium line is required to open the helium purge valve. It is assumed that some small blanket pressure will be loaded between the Shut-Off Valves (SOV's) and the engine for leak monitoring prior to liftoff.

P1150C, P1154C, and T1151A provide the required instrumentation for engine No. 1 helium monitoring. The operating functional paths for monitoring engine No. 1 helium are:

OFM 1= (ME 1) (ME 2)

OFM 7= (OFM 1) (ME 6 + ME 7) (ME 14)

The switchable functional path in the event of an OFM 7 failure is (OFM 5) (ME26) (see sec. 3.2, pneumatic supply). Loss of engine purge helium will cause engine shutdown. Source depletion may occur while attempting to isolate transducer failures; therefore, transducer failures should not be considered prior to switching sources during burns.

2.1.2 Main Engine No. 2. Engine No. 2 helium supply (fig. 2) has functional paths identical to those in the engine No. 1 helium supply. The operating functional paths used for performance monitoring FDA are:

OFM 2 = (ME 1) (ME 3)

OFM 8 = (OFM 2) (ME 8 + ME 9) (ME 17)

The switchable functional path in the event of an OFM 8 failure is (OFM 5) (ME 27) (see sec. 3.2).

2.1.3 Main Engine No. 3. Main Engine No. 3, helium supply (see fig. 3) has functional paths identical to those in the engine No. 1 helium supply. The operating functional paths used for performance monitoring FDA are:

OFM 3 = (ME 1) (ME 4)

OFM 9 = (OFM 3) (ME 10 + ME 11) (ME 20)

The switchable functional path in the event of an OFM 9 failure is (OFM 5) (ME 28) (see sec. 3.2).

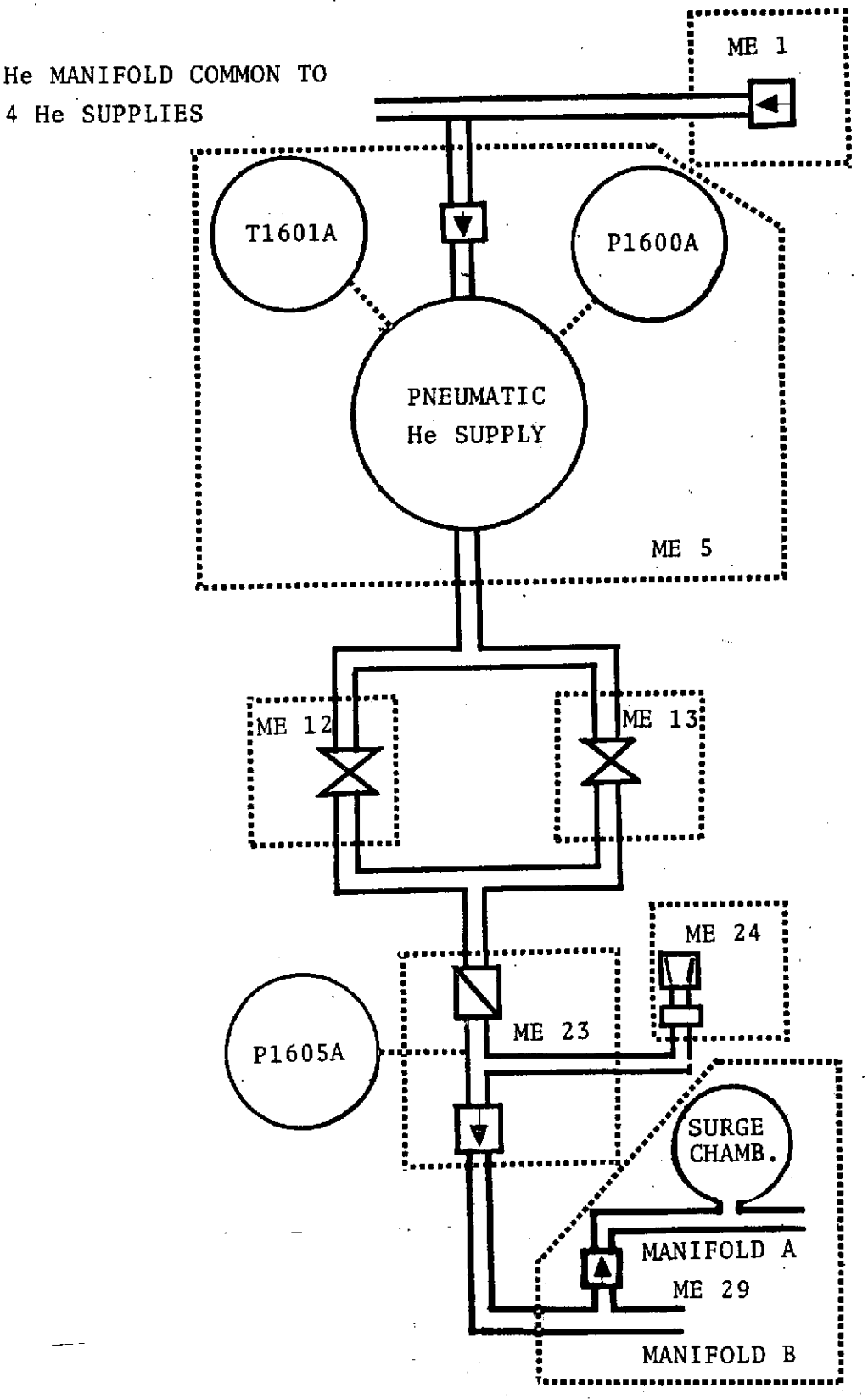

Figure 4. – Pneumatic He supply functional paths.

3.2 Pneumatic Helium Supply

The pneumatic helium supply (fig. 4) has functional paths identical to those in the engine No. 1 helium supply. This fourth helium source supplies pressure to the valves shown in figures 5 and 6. The operating functionals used for performance monitoring FDA are:

OFM 4 = (ME 1) (ME 5)

OFM 5 = (OFM 4) (ME 12 + ME 13) (ME 23)

The switchable functional paths in the event of OFM 5 failure are:

(OFM 3) (ME 28)

or (OFM 2) (ME 27)

or (OFM 1) (ME 26)

2.2.1 LO_2 supply. Three identical operating functional paths supply LO_2 to each engine and return GO_2 to the tank for pressurant. No redundant paths are available for switching. FDA is used to isolate failures in the path that may be corrected by the crew. The operating functional paths for LO_2 flow are (see fig. 7) the following:

Engine No. 1

OFM-10 = (MET 2) (ME 94) (ME 89) (ME 111)
(ME 112 + ME 113) (ME 95) (MET 1)

Engine No. 2

OFM-11 = (MET 2) (ME 94) (ME 90) (ME 115)
(ME 116 + ME 117) (ME 95) (MET 1)

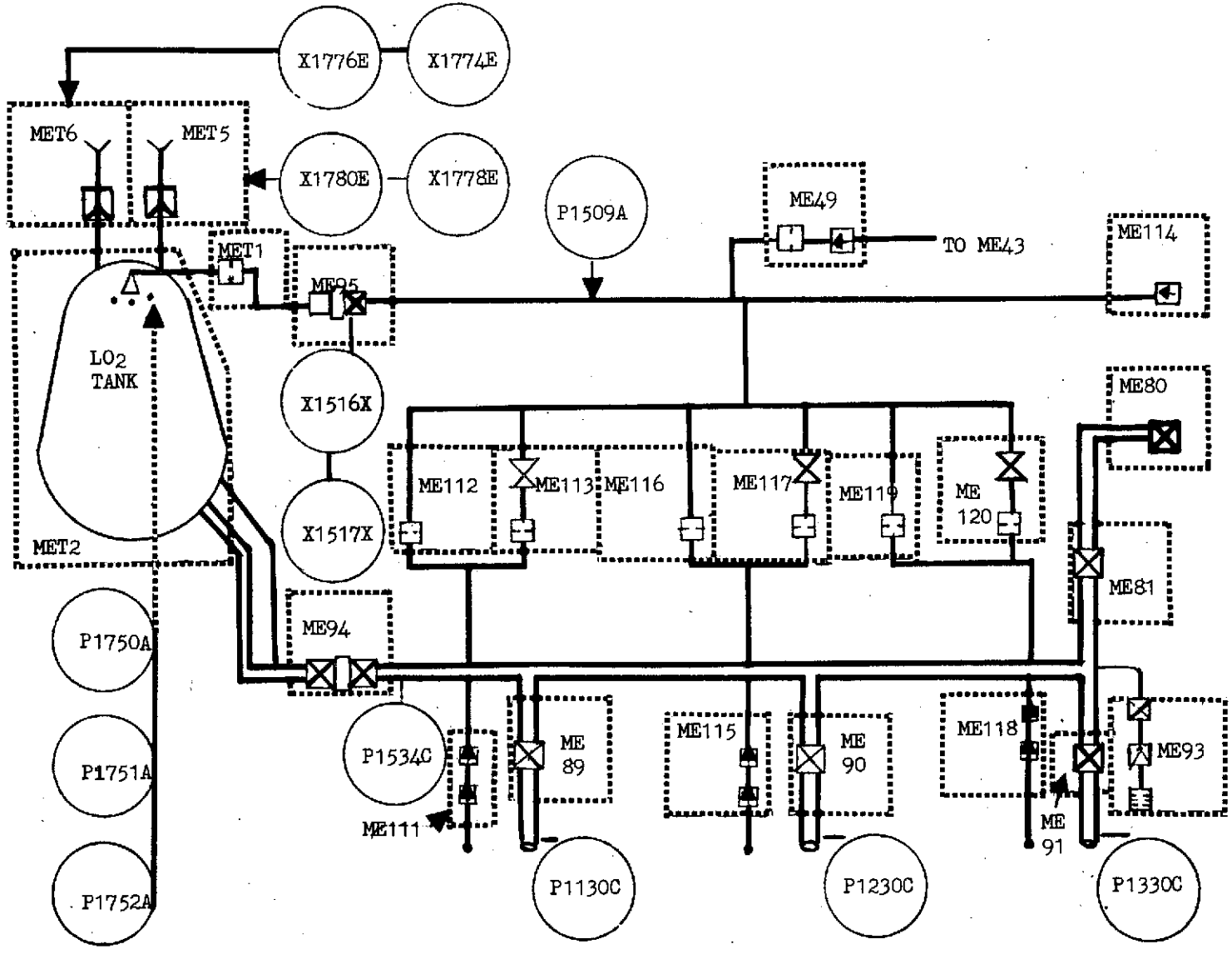

Figure 5. — LO_2 monitoring functional paths.

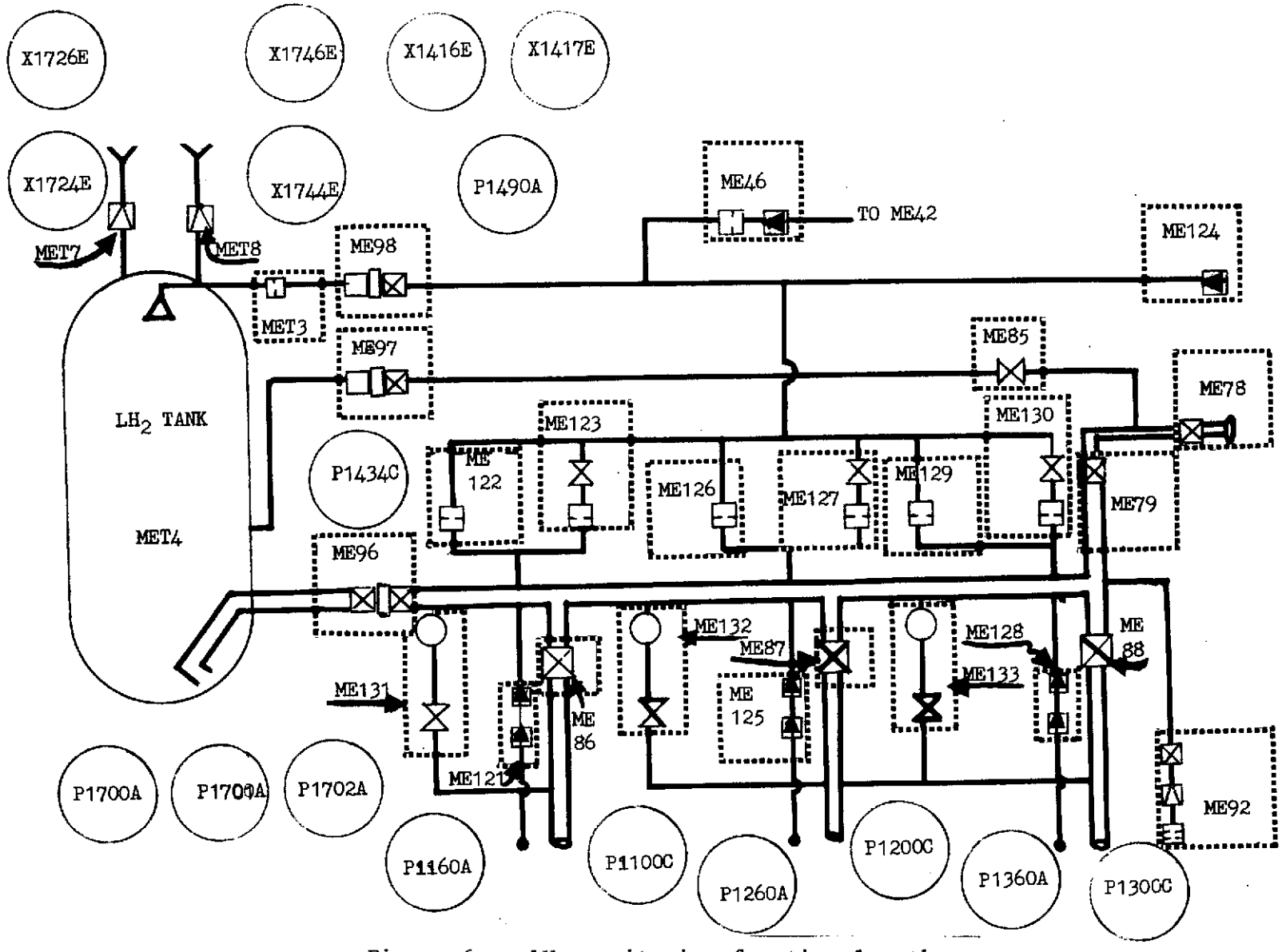

Figure 6. – LH_2 monitoring functional paths.

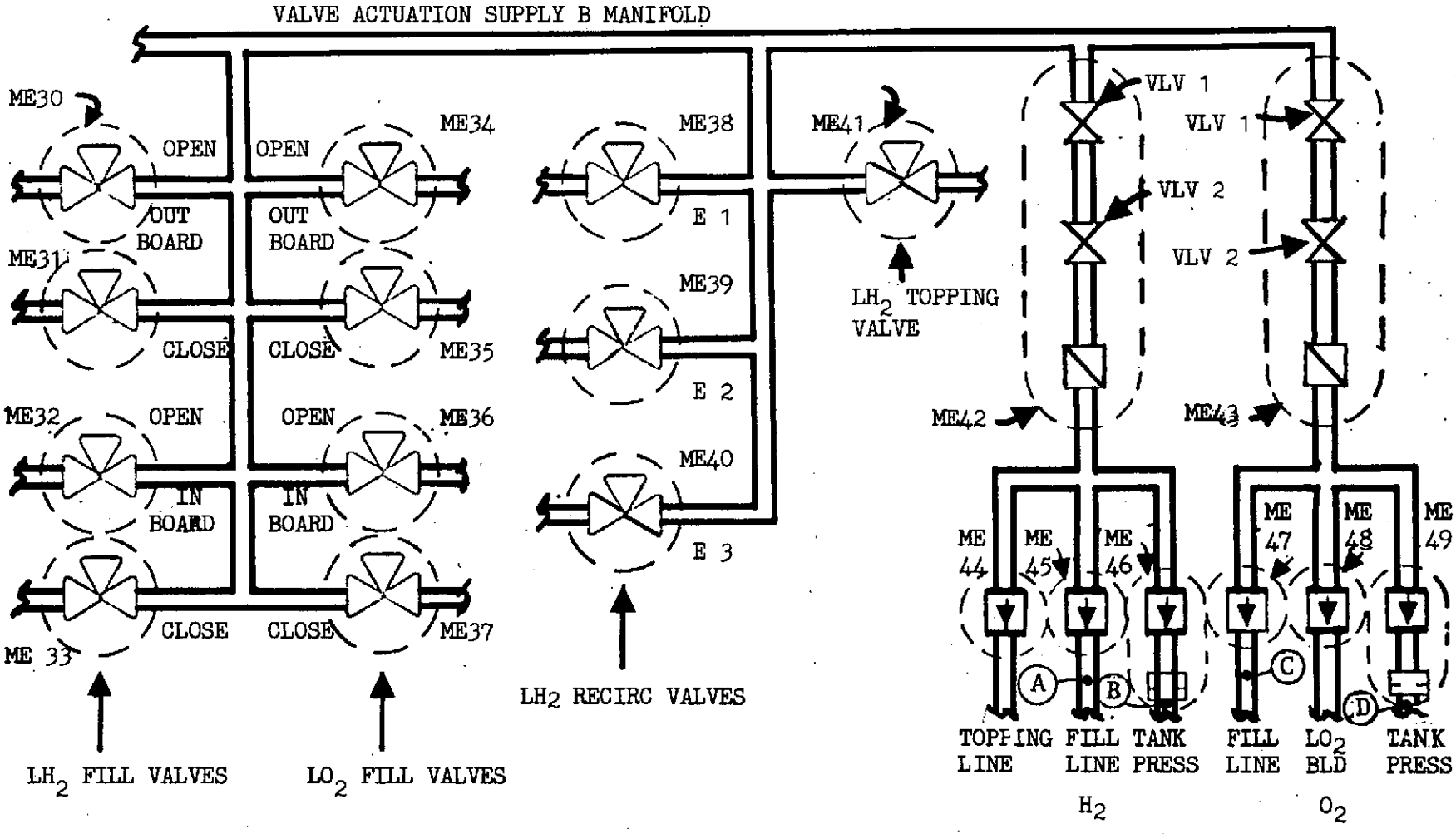

Figure 7. — Valve actuation supply B manifold functional paths.

Engine No. 3

OFM-12 = (MET 2) (ME 94) (ME 91) (ME 118)
(ME 119 + ME 120) (ME 95) (MET 1)

MET 2 is the LO_2 tank containing LO_2 and ullage volume for GO_2 tank pressurant. Tank pressure is maintained between 20 and 22 psia. Over pressurization protection is provided by vent valves in MET 5 and MET 6. ME-94 consist of two mutually helium activated shut-off valves at the external tank Orbiter interface. A momentary fail closed of these valves results in the loss of all main engines. ME 89 is a helium activated LO_2 prevalve. A fail closed condition results in loss of one engine. ME 111 consists of two check valves in the engine GO_2 outlet line. The check valves prevent GO_2 backflow through a failed engine. ME 112 is an orifice limiting flow of GO_2 tank pressurant. It is in parallel with ME 113, which is a second orifice and shut-off valve. The shut-off valve of ME 113 is normally open. As tank pressure approaches the upper limit a pressure switch closes the SOV. Tank pressurant flow is then limited to the orifice in ME 112. ME 95 consist of two Orbiter external tank interface shut-off valves for the GO_2 repress line. The tank valve is a close-on disconnect type. The Orbiter side is a helium-actuated shut-off valve. In the event of a fail closed condition, it can be commanded open from the crew panel.

MET 1 is an orifice that provides a final limit to pressurant flow to the tank. Components in the Engine 2 and 3 LO_2 functional paths provide identical functions.

3.2.2 LH_2 supply. Three identical operating functional paths supply LH_2 to each engine and return LH_2 to the tank for pressurant. No redundant paths are available for switching. FDA is used to isolate functional path failures which may be corrected by the crew (fig. 8). The operating functional paths for LH_2 are:

Engine No. 1
OFM 13 = (MET 4) (ME 96) (ME 86) (ME 121)
(ME 122 + ME 123) (ME 98) (MET 3)

Engine No. 2
OFM 14 = (MET 4) (ME 96) (ME 87) (ME 125)
(ME 126 + ME 127) (ME 98) (MET 3)

Engine No. 3
OFM 15 = (MET 4) (ME 96) (ME 88) (ME 128)
(ME 129 + ME 130) (ME 98) (MET 3)

MET 4 is the LH_2 tank containing LH_2 and an ullage volume for GH_2 pressurant. Tank pressure is maintained between 32 and 34 psia. Over pressurization protection is provided by vent valves in MET 7 and MET 8. ME 96 consists of two mutually helium activated shut-off valves, at the external tank Orbiter interface. A momentary fail closed of these valves results in the loss of all main engines. ME 86 is a helium activated LH_2 prevalve. A fail closed condition results in the loss of one engine.

ME 121 consists of two check valves in the engine GH_2 outlet line. The check valves prevent GH_2 back flow through a failed engine. ME 122 is an orifice limiting flow of GH_2 tank pressurant. It is in parallel with ME 123, a second

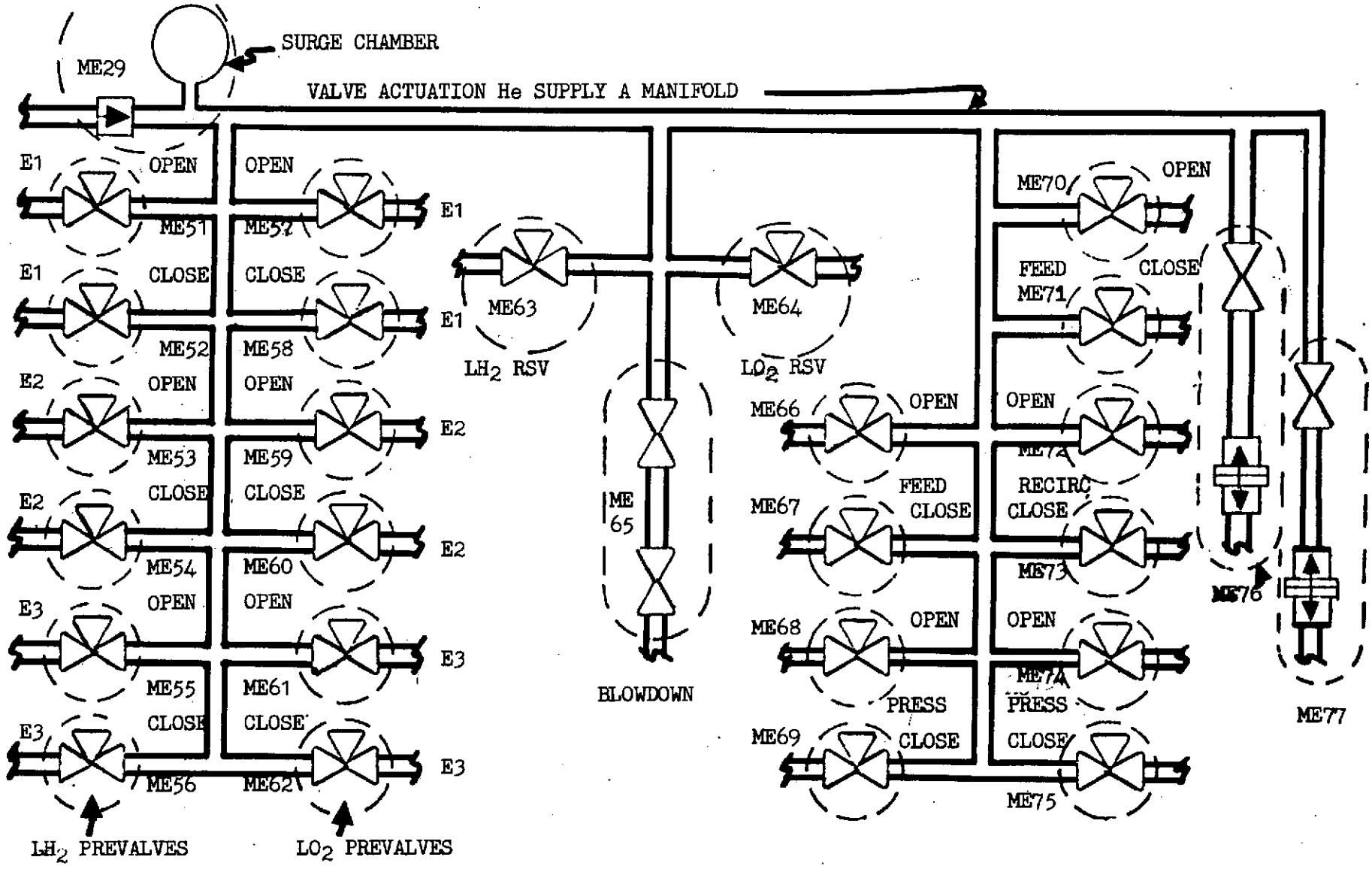

Figure 8. — Valve actuation He supply A manifold functional paths.

orifice and shut-off valve. The shut-off valve of ME 123 is normally open. As tank pressure approaches the upper limit a pressure switch closes the shut-off valve. Tank pressurant flow is then limited to the orifice in ME 122.

ME 98 consists of two Orbiter external tank interface shut-off valves for the GH_2 repress line. The tank valve is a close on disconnect type. The Orbiter side is a helium activated shut-off valve. In the event of a fail close condition, it can be commanded open from the crew panel.

MET 3 is an orifice that provides a final limit to GH_2 pressurant flow to the tank. Components in the engine 2 and 3 LH_2 functional paths provide identical functions.

3.3 Engine Monitoring

Each engine is monitored by its own dedicated controller during checkout and main engine burns. Failures are compiled in a fault data word. FDA will be used to annunciate these failures to the crew. In addition, seven controller parameters will shut down the engine if their limits are exceeded. In cases where it is desired to insure the engines do not shut down, these limit shut-downs will be inhibited by the crew. FDA will be used to monitor these parameters during the inhibit period. The first 32 data words from each controller are available to PMS. The data word list is presently being revised and it is anticipated that all data words in table 5 will be included in the first 32 data words.

3.3.1 Environment. Engine compartment environment will be monitored by two temperature sensors located in the engine compartment.

3.3.2 FDA measurements. Tables 1 through 5 define the measurements required and their justification for FDA. Those contained in Vol. 1, Part I, of the Master Measurement List (MML), are identified, also those presently assigned to performance monitoring are identified.

The OFI Measurement List, from the main propulsion panel meeting, November 28, 1973, is included as table 6. All measurements identified for FDA by this report are listed in table 6.

TABLE 1. – ENGINE NO. 1 He SUPPLY

Measurement Number	Measurement Identification	Justification for FDA	MML
V41P1150C	E_1 He Supply Press	Leak detection (preburn) Leak detection (burn)	Part I Software PM - Yes
V41P1154C	E_1 He Reg. Outlet Press	Leak detection (preburn) Regulator/SOV Failures (burn)	Part I Software PM - Yes
*V41T1151A	E_1 He Supply Temp	Heat and cold soak preburn leak detection only	Part I Flight PM - Yes
		*Needed for ground checkout only only.	
Operating Functional Paths		OFM 1 = (ME 1) (ME 2) OFM 7 = (OFM 1) (ME 6 + ME 7) (ME 14)	

TABLE 1. – ENGINE NO. 2 He SUPPLY (Continued)

Measurement Number	Measurement Identification	Justification for FDA	MML
V41P1250C	E_2 He Supply Press	Leak detection (preburn) Leak detection (burn)	Part 1 Software PM - No
V41P1254C	E_2 He Reg. Outlet Press	Leak detection (preburn) Regulators/SOV failures (burn)	Part 1 Software PM - Yes
*V41T1251A	E_2 He Supply Temp.	Heat and cold soak (preburn) Leak detection only	Part 1 Flight PM - Yes
		*Needed for ground checkout only.	
Operating Functional Paths		OFM 2 = (ME 1) (ME 3)	
		OFM 8 = (OFM 2) (ME 8 + ME 9) (ME 17)	

TABLE 1. – ENGINE NO. 3 He SUPPLY (Continued)

Measurement Number	Measurement Identification	Justification for FDA	MML
V41P1350C	E_3 He Supply Press	Leak detection (preburn) Leak detection (burn)	Part 1 Software PM - No
V41P1354C	E_3 He Reg. Outlet Press	Leak detection (preburn) Regulator/SOV failures (burn)	Part 1 Software PM - Yes
*V41T1251A	E_3 He Supply Temp	Heat and cold soak (preburn) Leak detection only	Part 1 Flight PM - Yes
		*Needed for ground checkout only.	
Operational Functional Paths		OFM 3 = (ME 1) (ME 4) OFM 9 = (OFM 3) (ME 10 + ME 11) (ME 20)	

TABLE 1. – PNEUMATIC He SUPPLY (Concluded)

Measurement Number	Measurement Identification	Justification for FDA	MML
V41P1600A	Pneumatic Valve	Leak detection (preburn)	Part 1
	H_e Supply Press	Leak detection (preburn)	Flight PM - Yes
V41P1605A	Pneumatic Valve	Leak detection (preburn)	Part 1
	H_e Reg Outlet Press	Regulator/SOV Failures (burn)	Flight PM - Yes
*V41T1601A	Pneumatic Valve	Heat and cold soak leak	Part 1
	H_e Supply Temp	detection	Flight PM - Yes
		*Needed for ground checkout only.	
Operating Functional Paths		OFM 4 = (ME 1) (ME 5)	
		OFM 5 = (OFM 4) (ME 12 + ME 13) ME 23	

TABLE 2. – LO_2 MONITORING FDA

Measurement Number	Measurement Identification	Justification for FDA	MML
T41P1750A	LO_2 Ullage Press #1	Primary repress monitoring and leak detection	Part 1 Flight PM No
T41P1751A	LO_2 Ullage Press #2	Primary repress monitoring and leak detection	Part 1 Flight PM No
T41P1752A	LO_2 Ullage Press #3	Primary repress monitoring and leak detection	Part 1 Flight PM No
V41P1130C	E1 LO_2 Inlet Press	Crew display backup primary inlet monitor	Part 1 Software PM NO
V41P1230C	E_2 LO_2 Inlet Press	Crew display backup inlet monitor primary	Part 1 Software PM No

TABLE 2. – LO_2 MONITORING FDA (Continued)

Measurement Number	Measurement Identification	Justification for FDA	MML
V41P1330C	E_3 LO_2 Inlet Press	Primary Crew Display backup inlet monitor	Part 1 Software PM No
V41P1354C	LO_2 Feed Manifold Press	Correlation Crew Display Backup inlet monitor	Part 1 Software PM Yes
V41P1590A	GO_2 Press Disc.	Correlation Repress fault isolation	Part 1 Flight PM Yes
V41X1516X	GO_2 Press Disc. Valve Open	Correlation Repress Fault isolation	Part 1 Software PM No
V41X1517X	GO_2 Press Disc Valve Closed	Correlation Repress fault isolation	

TABLE 2. – LO_2 MONITORING FDA (Continued)

Measurement Number	Measurement Identification	Justification for FDA	MML
V41X1774E	LO_2 Vent Valve 1 Closed	Correlation Repress fault isolation	
V41X1776E	LO_2 Vent Valve 1 Open	Correlation Repress fault isolation	
V41X1778E	LO_2 Vent Valve 2 Closed	Correlation Repress fault isolation	
V41X1780E	LO_2 Vent Valve 2 Open	Correlation Repress fault isolation	
V41T1161A	E_1 GH_2 Outlet Temperature	Correlation Repress fault isolation	
V41T1261A	E_2 GH_2 Outlet Temperature	Correlation Repress fault isolation	

TABLE 2. – LO_2 MONITORING FDA (Concluded)

Measurement Number	Measurement Identification	Justification for FDA	MML
V41T1361A	E_3 GH_2 Outlet Temperature	Correlation Repress fault isolation	

TABLE 3. – LH_2 MONITORING FDA

Measurement Number	Measurement Identification	Justification for FDA	MML
V41P1300C	E_3 LH_2 Eng Inlet Press	Primary Backup crew display Eng. inlet monitor	Part 1 Software PM No
V41P1434C	LH_2 Feed Manifold Press	Correlation Backup crew display inlet fault detection	Part 1 Software PM Yes
V41P1160A	GH_2 Outlet Press E_1	Correlation Repress Failure isolation	
V41P1260A	GH_2 Outlet Press E_2	Correlation Repress Failure isolation	
V41P1360A	GH_2 Outlet Press E_3	Correlation Repress Failure isolation	

TABLE 3. – LH_2 MONITORING FDA (Continued)

Measurement Number	Measurement Identification	Justification for FDA	MML
T41P1700A	LH_2 Ullage Press #1	Primary Repress Failure Isolation Leak Detection	Part 1 Flight PM Yes
T41P1701A	LH_2 Ullage Press #2	Primary Repress Failure Isolation Leak Detection	Part 1 Flight PM Yes
T41P1702A	LH_2 Ullage Press #3	Primary Repress Failure Isolation Leak detection	Part 1 Flight
V41P1100C	E_1 LH_2 Eng. Inlet Press	Primary Backup Crew Disposition Eng. Inlet Monitor	Part 1 Software PM No
V41P1200C	E_2 LH_2 Eng. Inlet Press	Primary Backup Crew Disposition Eng. Inlet Monitor	Part 1 Software PM No

TABLE 3. — LH_2 MONITORING FDA (Continued)

Measurement Number	Measurement Identification	Justification for FDA	MML
V41P1490A	GH_2 Press Disc.	Correlation Repress Failure Isolation	Part 1 Flight PM Yes
T41X1724E	LH_2 Vent Valve #1 Closed	Correlation Repress Failure Isolation	
T41X1126E	LH_2 Vent Valve #1 Open	Correlation Repress Failure Isolation	
T41X1744E	LH_2 Vent Valve #2 Closed	Correlation Repress Failure Isolation	
T41X1746E	LH_2 Vent Valve #2 Open	Correlation Repress Failure Isolation	

TABLE 3. – LH_2 MONITORING FDA (Concluded)

Measurement Number	Measurement Identification	Justification for FDA	MML
V41X1416E	GH_2 Press Disc. Valve Open	Correlation Repress Failure Isolation	Part 1 Software PM No
V41X1417E	GH_2 Press Disc. Valve Closed	Correlation Repress Failure Isolation	

TABLE 4. — ENVIRONMENT ENGINE COMPARTMENT FDA

Measurement Number	Measurement Identification	Justification for FDA	MML
T21 OFI List	Eng. Comp.	Over Temp. Monitoring	
V41 None	Amb. Temp. 1	During burns	
T22 OFI List	Eng. Comp.	Over Temp. Monitoring	
V41 None	Amb. Temp. 2	During burns	

TABLE 5. – CONTROLLER DATA WORDS FOR FDA

Present Data Word Assignment	Measurement Identification	Justification for FDA	MML
DW-1	Engine Identification	Primary Data Tag	
DW-2	Engine Identification	Primary Data Tag	
DW-3	ME Status	Precondition checks	Part 1 Software PM No
DW-5	Thrust	Correlation for Eng. Inlet Press	Part 1 Software PM No
DW-6	Failure ID	Primary Failure Annunciation	Part 1 Software PM No
DW-7	Test Data	Correlation Fault Annunciation	Part 1 Software PM No

TABLE 5. – CONTROLLER DATA WORDS FOR FDA (Continued)

Present Data Word Assignment	Measurement Identification	Justification for FDA	MML
DW-8	Parameter Value	Correlation Fault Annunciation	
DW-40	HPFTP Disc Temp	Monitoring During Limit Inhibit	Part 1 Software PM No
DW-41	HPFT Shaft Speed	Monitoring During Limit Inhibit	
DW-54	HPOTP Disc. Temp.	Monitoring During Limit Inhibit	Part 1 Software PM No
DW-55	HPOT Boost Stage Press Disc.	Monitoring During Limit Inhibit	
DW-56	HPOT Boost Stage Press Disc.	Monitoring During Limit Inhibit	

TABLE 5. – CONTROLLER DATA WORDS FOR FDA (Concluded)

Present Word Data Word Assignment	Measurement Identification	Justification for FDA	MML
DW-57	HPOT Shaft Speed	Monitoring During Limit Inhibit	Part 1 Software PM No
DW-64	Ox - Tank Pressurant Press	Monitoring During Limit Inhibit	Part 1 Software PM No
DW-65	Ox - Tank Pressurant Press	Monitoring During Limit Inhibit	Part 1 Software PM No
DW-76	HPOT Intermediate Seal Purge Press	Monitoring During Limit Inhibit	

TABLE 6. – MPS OFI INSTRUMENTATION LIST
EXTERNAL TANK PRESSURES AND TEMPERATURES

CODE	MEASUREMENT #	NAME	RANGE	PURPOSE*	S/S
P1T	T41P1750A	LO_2 Ullage Press #1	0-30 psia	4	10
P2T	T41P1751A	LO_2 Ullage Press #2	0-30 psia	4	10
P3T	T41P1752A	LO_2 Ullage Press #3	0-30 psia	4	10
P4T	T41P1700A	LH_2 Ullage Press #1	0-50 psia	4	10
P5T	T41P1701A	LH_2 Ullage Press #2	0-50 psia	4	10
P6T	T41P1702A	LH_2 Ullage Press #3	0-50 psia	4	10
T1T	T41T1755A	LO_2 Ullage Temp	-430 + 40° F	9	1
T2T	T41T1705A	LH_2 Ullage Temp	-430 - 40° F	9	1

*Purpose code defined in Master Measurement List, Volume 1.

TABLE 6. – MPS OFI INSTRUMENTATION LIST
(Continued) EXTERNAL TANK DISCRETES

CODE	MEASUREMENT #	NAME	RANGE	PURPOSE	S/S
X1T	T41X1730X	LH_2 Depletion Sensor #1		1	10
X2T	T41X1731X	LH_2 Depletion Sensor #2		1	10
X3T	T41X1732X	LH_2 Depletion Sensor #3		1	10
X4T	T41X1733X	LH_2 Depletion Sensor #4		1	10
X6T	T41X1760E	LO_2 Liquid Level 2% #1		9	10
X7T	T41X1761E	LO_2 Liquid Level 2% #2		8	10
X8T	T41X1762E	LO_2 Liquid Level 5%		9	10
X9T	T41X1765E	LO_2 Liquid Level 98% #1		8	10
X10T	T41X1766E	LO_2 Liquid Level 98% #2		8	10
X11T	T41X1767E	LO_2 Liquid Level 99.85%		8	10
X12T	T41X1768E	LO_2 Liquid Level 100% #1		8	10
X13T	T41X1769E	LO_2 Liquid Level 100% #2		8	10
X14T	T41X1770E	LO_2 Liquid Level 100.15%		8	10
X15T	T41X1771E	LO_2 Liquid Level 102%		8	10
X16T	T41X1710E	LH_2 Liq Level 2% #1		9	10
X17T	T41X1711E	LH_2 Liq Level 2% #2		8	10
X18T	T41X1712E	LH_2 Liq Level 5%		9	
X19T	T41X1715E	LH_2 Liq Level 98% #1		8	10

TABLE 6. – MPS OFI INSTRUMENTATION LIST (Continued)

EXTERNAL TANK DISCRETES

CODE	MEASUREMENT #	NAME	RANGE	PURPOSE	S/S
X20T	T41X1716E	LH_2 Liq Level 98% #1		8	10
X21T	T41X1717E	LH_2 Liq Level 99.7%		8	10
X22T	T41X1718E	LH_2 Liq Level 100% #1		8	10
X23T	T41X1719E	LH_2 Liq Level 100% #2		8	10
X24T	T411720E	LH_2 Liq Level 100.3%		8	10
X25T	T41X1721E	LH_2 Liq Level 102%		8	10
X26T	T41X1776E	LO_2 Vent Valve #1 Open		5	10
X27T	T41X1774E	LO_2 Vent Valve #1 Closed		5	10
X28T	T41X1780E	LO_2 Vent Valve #2 Open		5	10
X29T	T41X1778E	LO_2 Vent Valve #2 Closed		5	10
X30T	T41X1726E	LH_2 Vent Valve #1 Open		5	10
X31T	T41X1724E	LH_2 Vent Valve #1 Closed		5	10
X32T	T41X1746E	LH_2 Vent Valve #2 Open		5	10
X33T	T41X1744E	LH_2 Vent Valve #2 Closed		5	10

TABLE 6. – MPS OFI INSTRUMENTATION LIST (Continued)

ORBITER PRESSURES

CODE	MEASUREMENT #	NAME	RANGE	PURPOSE	S/S
P1	V41P1130C	E_1 LO_2 Eng Inlet Press	0-400 psia	9	25
P2	V41P1230C	E_2 LO_2 Eng Inlet Press	0-400 psia	9	25
P3	V41P1330C	E_3 LO_2 Eng Inlet Press	0-400 psia	9	25
P4	V41P1534C	LO_2 Feed Manifold Press	0-400 psia	4	10
P5	V41P1100C	E_1 LH_2 Eng Inlet Press	0-200 psia	9	25
P6	V41P1200C	E_2 LH_2 Eng Inlet Press	0-200 psia	9	25
P7	V41P1300C	E_3 LH_2 Eng Inlet Press	0-200 psia	9	25
P8	V41P1434C	LH_2 Feed Manifold Press	0-200 psia	4	10
P9	V41P1160A	E_1 GH_2 Outlet Press	0-5000 psia	4	10
P10	V41P1260A	E_2 GH_2 Outlet Press	0-5000 psia	4	10
P11	V41P1360A	E_3 GH_2 Outlet Press	0-5000 psia	4	10
P12	V41P1150C	E_1 H_e Supply Press	0-5000 psia	1	1
P13	V41P1250C	E_2 H_e Supply Press	0-5000 psia	1	1
P14	V41P1350C	E_3 H_e Supply Press	0-5000 psia	1	1
P15	V41P1600A	Pneu Valve H_e Supply Press	0-5000 psia	1	10
P16	V41P1154C	E_1 H_e Reg. Outlet Press	0-1000 psia	4	10
P17	V41P1254C	E_2 H_e Reg. Outlet Press	0-1000 psia	4	10
P18	V41P1354C	E_3 H_e Reg. Outlet Press	0-1000 psia	4	10

TABLE 6. – MPS OFI INSTRUMENTATION LIST (Continued)

ORBITER PRESSURES

CODE	MEASUREMENT #	NAME	RANGE	PURPOSE	S/S
P19	V41P1605A	Pneu Valve H_e Reg. Outlet Press	0-1000 psia	4	10
P20	V41P1590A	GO_2 Press Disc Press	0-1000 psia	4	10
P21	V41P1490A	GH_2 Press Disc Press	0-1000 psia	4	10
P22		LO_2 Tank ΔP		8	
P23		LH_2 Tank ΔP		8	

TABLE 6. — MPS OFI INSTRUMENTATION LIST (Continued)

ORBITER TEMPERATURES

CODE	MEASUREMENT #	NAME	RANGE	PURPOSE	S/S
T1	V41T1131C	E1 LO_2 Eng Inlet Temp	-320 to -270° F	9	1
T2	V41T1231C	E2 LO_2 Eng Inlet Temp	-320 to -270° F	9	1
T3	V41T1331C	E3 LO_3 Eng Inlet Temp	-320 to -270° F	9	1
*T4	V41T1528A	LO_2 Feed Manifold Disc Temp	-325 to +125° F	9	1
T5	V41T1101C	E1 LH_2 Eng Inlet Temp.	-430 to -370° F	9	1
T6	V41T1201C	E2 LH_2 Eng Inlet Temp	-430 to -370° F	9	1
T7	V41T1301C	E3 LH_2 Eng Inlet Temp.	-430 to -370° F	9	1
T8	V41T1428A	LH_2 Feed Manifold Disc Temp	-430 to -379° F	9	1
T9	V41T1171A	E1 GO_2 Outlet Temp	-250 to +1000° F	9	1
T10	V41T1271A	E2 GO_2 Outlet Temp	-250 to +1000° F	9	1
T11	V41T1371A	E3 GO_2 Outlet Temp	-250 to +1000° F	9	1
T12	V41T1591A	GO_2 Press Disc Temp	-250 to +1000° F	9	1
T13	V41T1161A	E1 GH_2 Outlet Temp	-65 to +500° F	9	1
T14	V41T1261A	E2 GH_2 Outlet Temp	-65 to +500° F	9	1
T15	V41T1361A	E3 GH_2 Outlet Temp	-65 to +500° F	9	1
T16	V41T1491A	GH_2 Press Disc Temp	-65 to +500° F	9	1
T17	V41T1601A	Pneu Valve H_e Supply Temp	-65 to +500° F	1	1
T18	V41T1151A	E1 H_e Supply Temp	-65 to +500° F	10	1

TABLE 6. – MPS OFI INSTRUMENTATION LIST (Continued)

ORBITER TEMPERATURES

CODE	MEASUREMENT #	NAME	RANGE	PURPOSE	S/S
T19	V41T1251A	E2 H_e Supply Temp	-65 to +500° F	10	1
T20	V41T1351A	E3 H_e Supply Temp	-65 to +500° F	10	1
T21		Eng Comp Amb Temp #1		8	
T22		Eng Comp Amb Temp #2		8	
T23	V41T1060A	E1 Controller H/W Temp	-200 to +400° F	4	1
T24	V41T1061A	E2 Controller H/W Temp	-200 to +400° F	4	1
T25	V41T1062A	E3 Controller H/W Temp	-200 to +400° F	4	1

TABLE 6. – MPS OFI INSTRUMENTATION LIST (Continued)

ORBITER DISCRETES

CODE	MEASUREMENT #	NAME	LOW	HIGH	PURPOSE	S/S
X1	V41X1580X	LO_2 Depletion Sensor #1	Wet	Dry	1	10
X2	V41X1582X	LO_2 Depletion Sensor #2	Wet	Dry	1	10
X3	V41X1584X	LO_2 Depletion Sensor #3	Wet	Dry	1	10
X4	V41X1586X	LO_2 Depletion Sensor #4	Wet	Dry	1	10
X6	V41X1510E	LO_2 InB Fill Valve Open			9	
X7	V41X1509X	LO_2 InB Fill Valve Closed	On	Off	9	10
X8	V41X1413E	LO_2 OutB Fill Valve Open			9	
X9	V41X1514X	LO_2 OutB Fill Valve Closed	On	Off	9	10
X10	V41X1409E	LH_2 InB Fill Valve Open			9	
X11	V41X1410X	LH_2 InB Fill Valve Closed	On	Off	9	10
X12	V41X1413E	LH_2 OutB Fill Valve Open			9	
X13	V41X1414X	LH_2 OutB Fill Valve Closed	On	Off	9	10
X14	V41X1553E	LH_2 Topping Fill Valve Open			9	
X15	V41X1456X	LH_2 Topping Fill Valve Closed			9	
X16	V41X1134X	E1 LO_2 Pre Valve Open	On	Off	9	10
X17	V41X1234X	E2 LO_2 Pre Valve Open	On	Off	9	10

TABLE 6. – MPS OFI INSTRUMENTATION LIST (Continued)

ORBITER DISCRETES

CODE	MEASUREMENT #	NAME	LOW	HIGH	PURPOSE	S/S
X18	V41X1334X	E3 LO_2 Pre Valve Open	On	Off	9	10
X19	V41X1135E	E1 LO_2 Pre Valve Closed	On	Off	9	10
X20	V41X1235E	E2 LO_2 Pre Valve Closed			9	
X21	V41X1335E	E3 LO_2 Pre Valve Closed			9	
X22	V41X1104X	E1 LH_2 Pre Valve Open	On	Off	9	10
X23	V41X1204X	E2 LH_2 Pre Valve Open	On	Off	9	10
X24	V41X1304X	E3 LH_2 Pre Valve Open	On	Off	9	10
X25	V41X1105E	E1 LH_2 Pre Valve Closed			9	10
X26	V41X1205E	E2 LH_2 Pre Valve Closed	On	Off	9	10
X27	V41X1305E	E3 LH_2 Pre Valve Closed			9	
X28	V41X1109E	E1 LH_2 Recirc Valve Open	On	Off	8	10
X29	V41X 1209E	E2 LH_2 Recirc Valve Open	On	Off	8	10
X30	V41X1309E	E3 LH_2 Recirc Valve Open	On	Off	8	10
X31	V41X1110E	E1 LH_2 Recirc Valve Closed	On	Off	8	10
X32	V41X1210E	E2 LH_2 Recirc Valve Closed	On	Off	8	10
X33	V41X1310E	E3 LH_2 Recirc Valve Closed	On	Off	8	10

TABLE 6. – MPS OFI INSTRUMENTATION LIST (Continued)

ORBITER DISCRETES

CODE	MEASUREMENT #	NAME	LOW	HIGH	PURPOSE	S/S
*X34	V41X1545E	LO_2 RSV Open			9	10
X35	V41X1546X	LO_2 RSV Closed			9	10
X36	V41X1445E	LH_2 RSV Open			9	10
X37	V41X1446E	LH_2 RSV Closed			9	10
X38	V41X1529X	LO_2 F/L Disc Valve Open	On	Off	9	10
X39	V41X1530E	LO_2F/L Disc Valve Closed			9	10
X40	V41X1429X	LH_2 F/L Disc Valve Open	On	Off	9	10
X41	V41X1430E	LH_2 F/L Disc Valve Closed			9	10
X42	V41X1419E	LH_2 Recirc Disc Valve Open	On	Off	4	10
X43	V41X1420E	LH_2 Recird Disc Valve Closed			4	10
X44	V41X1516X	GO_2 Press Disc Valve Open	On	Off	9	10
X45	V41X1517E	GO_2 Press Disc Valve Closed			9	10
X46	V41X1415E	GH_2 Press Disc Valve Open			9	
X47	V41X1417E	GH_2 Press Disc Valve Closed			9	

TABLE 6. – MPS OFI INSTRUMENTATION LIST (Concluded)

ORBITER SPEEDS

CODE	MEASUREMENT #	NAME	UNITS	PURPOSE	S/S
R1	V41R1115A	E1 LH_2 Recirc Pump Speed	RPM	5	10
R2	V41R1215A	E2 LH_2 Recirc Pump Speed	RPM	5	10
R3	V41R1315A	E3 LH_2 Recirc Pump Speed	RPM	5	10

4.0 MEASUREMENT TO FUNCTIONAL PATH CORRELATION

The operational instrumentation measurements required for FDA are compiled in table 7. The normal operating range, functional path correlation, and mission phases to be monitored are also tabulated.

TABLE 7. – PMS MEASUREMENT DATA

MAIN PROPULSION SUBSYSTEM

MEASUREMENT	TYPE*	RANGE	FUNCTIONAL PATH	REMARKS
T1151A	P*	500 - 580° R	ME 2	Preburn only
P1150C	P	(See fig. 9)	OFM 7	Curve fit for burns
P1154C	P	715 - 785 PSIA	OFM 7	
T1251A	P	500 - 580° R	ME 3	Preburn only
P1250C	P	(See fig. 9)	OFM 8	Curve fit for burns
P1254C	P	715 - 785 PSIA	OFM 8	
T1351A	P	500 - 580° R	ME 4	Preburn only
P1350C	P	(See fig. 9)	OFM 9	Curve fit for burns
P1354C	P	715 - 785 PSIA	OFM 9	
T1601A	P	500 - 580° R	ME 5	Preburn only
P1600C	P	(See fig. 9)	OFM 5	Profile fit
P1605C	P	715 - 785 PSIA	OFM 5	
Controller DW 5				See Table 5

*P = Primary

TABLE 7. – PMS MEASUREMENT DATA
MAIN PROPULSION SUBSYSTEM (Continued)

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
T41P1750A	P	20-27 psia	OFM 10-11-12	Vote 2 of 3 = good.
T41P1751A	P	20-27 psia	OFM 10-11-12	Vote 2 of 3 = good.
T41P1752A	P	20-27 psia	OFM 10-11-12	Vote 2 of 3 = good.
V41P1590A	S*	1000 - 5500 psia	OFM 10-11-12	Max. Min. limit PM limit may be different.
V41X1516X	S	Event	OFM 10-11-12	
V41X1517X	S	Event	OFM 10-11-12	
V41X1774E	S	Event	OFM 10-11-12	
V41X1776E	S	Event	OFM 10-11-12	
V41X1778E	S	Event	OFM 10-11-12	
V41X1780E	S	Event	OFM 10-11-12	
V41P1130C	P	23.3 - 375 psia	OFM 10	Max. Min. limits may be difficult.
V41P1230C	P	23.3 - 375 psia	OFM 11	Max. Min. limits may be difficult.
V41P1330C	P	23.3 - 375 psia	OFM 12	Max. Min. limits may be difficult.
V41P1534C	S	23.3 - 375 psia	OFM 10-11-12	Max. Min. limits may be difficult.
V41P1700A	P	32-39 psia	OFM 13-14-15	Vote 2 of 3 = good.
V41P1701A	P	32-39 psia	OFM 13-14-15	Vote 2 of 3 = good.
V41P1702A	P	32-39 psia	OFM 13-14-15	Vote 2 of 3 = good.
V41P1100C	P	20-130 psia	OFM 13	Limits are Min. and Max. spike. Require further refinement.

*S = Correlation

TABLE 7. – PMS MEASUREMENT DATA
MAIN PROPULSION SUBSYSTEM (Continued)

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V41P1200C	P	20-130 psia	OFM 14	Limits are Min. and Max. spike. Require further refinement.
V41P1300C	P	20-130 psia	OFM 15	Limits are Min. and Max. spike. Require further refinement.
V41P1434C	S	20-130 psia	OFM 13-14-15	
V41X1726E	S		OFM 13-14-15	
V41X1724E	S		OFM 13-14-15	
V41X1746E	S		OFM 13-14-15	
V411744E	S		OFM 13-14-15	
V41X1516E	S		OFM 13-14-15	
V41X1517E	S		OFM 13-14-15	
V41X1490A	S	1500 4500 psia	OFM 13-14-15	Max. Min. limit PM limit may be different
V41P1160A	S	TBD	OFM 13	
V41P1260A	S	TBD	OFM 14	
V41P1360A	S	TBD	OFM 15	
V41S1611E	Precond.	On - Off		Precondition check
V41S1613E	Precond.	On - Off		Precondition check
V411616E	Precond.	On - Off		Precondition check
V41S1613E	Precond.	On - Off		Precondition check
V41S1616E	Precond.	On - Off		Precondition check
T21 (OFI List)				Environment
T22 (OFI List)				Environment

5.0 MEASUREMENT LIMITS FOR FAULT DETECTION AND ANNUNCIATION

Table 8 defines the hard limits to be used for FDA, and the correlation checks required in the event a primary measurement fails the hard limit check.

Soft limits have not been included since they are not yet defined.

TABLE 8. – PMS MEASUREMENT REQUIREMENTS

SUBSYSTEM: Main Propulsion

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH	PRE-CONDITION TEST		F D A									
	HARDWARE STATUS	CONFIGURATION CHECK	SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION CHECK	SYSTEM STATUS LIGHT
			HIGH	LOW		HIGH	LOW	HIGH	LOW		
• V41P1350C (P) • E_3 He Supply P • OFM 9						Fig. 11				1351 1354	
• V41P1354C (P) E_3 He Reg Outlet P • OFM 9						715 psia	785 psia				
• T1601A (S) Pneu Valve He • ME 5						500°R	580°R				
• V41P1600A (P) Pneu Valve • He Supply Press • OFM 5						Fig. 11				1601 1605	

TABLE 8. – PMS MEASUREMENT REQUIREMENTS
(Continued)

SUBSYSTEM: Main Propulsion

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH	PRE-CONDITION TEST		F D A									
	HARDWARE STATUS	CONFIGURATION CHECK	SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION CHECK	SYSTEM STATUS LIGHT
			HIGH	LOW		HIGH	LOW	HIGH	LOW		
• V41P1605A (P) • Pneu Valve He Outlet Reg Press • OFM 5						715 psia	785 psia				
• Controller (Pre-cond) • Data Word 1 • Eng Status											
• V41T1151A (S) • E1 He Supply Temp. • ME2						500°R	580°R				
• V41P1150C (P) • E1 He Reg. Outlet • OFM 7						Fig. 11					1151 1154
• V41P1154C (P) • E1 He Reg. Outlet • OFM 7						715 psia	785 psia				

TABLE 8. – PMS MEASUREMENT REQUIREMENTS
(Continued)

SUBSYSTEM: Main Propulsion

PMS ACTIVITY / SYSTEM DATA: ● MEASUREMENT NO. ● MEASUREMENT ID ● FUNCTIONAL PATH	PRE-CONDITION TEST		F D A								
			SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION CHECK	SYSTEM STATUS LIGHT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW		
● V41T1251A (S) ● E_2 He Supply Temp ● ME 3						500	580°R				
● V41P1250C (P) ● E1 He Supply ● OFM 8						Fig. 11					1251 1254
● V41P1254C (P) ● E2 He Reg Outlet ● OFM 8						715 psia	785 psia				
● V41T1351A (S) ● E3 He Supply Temp						500°R	580°R				
● V41S1611E (S) ● Pneu 1 Cross ● Over Open Cmd.											

TABLE 8. – PMS MEASUREMENT REQUIREMENTS
(Continued)

SUBSYSTEM: Main Propulsion

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH	PRE—CONDITION TEST		F D A									
			SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING				
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	CORRELATION CHECK	SYSTEM STATUS LIGHT
• V41S1613E (S) • Pneu 2 Cross Over Open Cmd.											
• V41S1616E (S) • Pneu 3 Cross Over Open Cmd.											
• V41X1776E (S) • LO_2 Vent Valve 1 Open • OFM 10-11-12											
• V41X1778E (S) • LO_2 Vent Valve 2 Closed • OFM 10-11-12											

TABLE 8. – PMS MEASUREMENT REQUIREMENTS
(Continued)

SUBSYSTEM: Main Propulsion

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH	PRE—CONDITION TEST		F D A									
	HARDWARE STATUS	CONFIGURATION CHECK	SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION CHECK	SYSTEM STATUS LIGHT
			HIGH	LOW		HIGH	LOW	HIGH	LOW		
• V41X1780E (S) LO_2 Vent Valve 2 Open • OFM 10-11-12											
• V41P1130C (P) E1 LO_2 Eng Inlet Press • OFM 10						375	23.3			1534	
• V41P1230C (P) E2 LO_2 Eng Inlet Press • OFM 11						375	23.3			1534	
• V41P1330C (P) E3 LO_2 Eng Inlet Press • OFM 12						375	23.3			1534	

TABLE 8. – PMS MEASUREMENT REQUIREMENTS
(Continued)

SUBSYSTEM: Main Propulsion

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH	PRE-CONDITION TEST		F D A									
			SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION CHECK	SYSTEM STATUS LIGHT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW		
• V41P1534C (S) • LO_2 Feed Manifold Press • OFM 10-11-12											
• T41P1750A (P) • LO_2 Ullage P1 • OFM 10-11-12						27 psia	20 psia			1590 1774 1776 1778 1780	
• T41P1751A (P) • LO_2 Ullage P2 • OFM 10-11-12						27 psia	20 psia			1590 1774 1776 1778 1780	
• T41P1752A (P) • LO_2 Ullage P3 • OFM 10-11-12						27 psia	20 psia			1590 1774 1776 1778 1780	

TABLE 8. – PMS MEASUREMENT REQUIREMENTS
(Continued)

SUBSYSTEM: Main Propulsion

PMS ACTIVITY / SYSTEM DATA: ● MEASUREMENT NO. ● MEASUREMENT ID ● FUNCTIONAL PATH	PRE—CONDITION TEST		F D A									
	HARDWARE STATUS	CONFIGURATION CHECK	SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION CHECK	SYSTEM STATUS LIGHT
			HIGH	LOW		HIGH	LOW	HIGH	LOW		
● V41P1590A (S) ● GO_2 Disc Press ● OFM 10-11-12						5500 psia	1000 psia			1516 1517	
● V41X1516X (S) ● GO_2 Press Disc Valve Open ● OFM 10-11-12											
● V41X1517X (S) GO_2 Press Disc ● Valve Closed ● OFM 10-11-12											
● V41X1774E (S) LO_2 Vent Valve ● 1 Closed ● OFM 10-11-12											

TABLE 8. – PMS MEASUREMENT REQUIREMENTS
(Continued)

SUBSYSTEM: Main Propulsion

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH	PRE—CONDITION TEST		F D A									
			SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION CHECK	SYSTEM STATUS LIGHT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW		
• T41X1746E (S) LH_2 Vent Valve • 2 Open • OFM 13-14-15											
• V41P1160A (S) GH_2 Outlet • Press E1 • OFM 13						TBD	TBD				
• V41P1761A (S) GH_2 Outlet • Press E2 • OFM 14						TBD	TBD				
• V41P1361A (S) GH_2 Outlet • Press E3 • OFM 15						TBD	TBD				

TABLE 8. — PMS MEASUREMENT REQUIREMENTS
(Continued)

SUBSYSTEM: Main Propulsion

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH	PRE—CONDITION TEST		F D A									
			SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION CHECK	SYSTEM STATUS LIGHT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW		
• V41X1416E (S) GH_2 Press Disc • Valve Open • OFM 13-14-15											
• V41X1417E (S) GH_2 Press Disc • Valve Closed • OFM 13-14-15											
• V41P1434C (S) LN_2 Feed • Manifold Press • OFM 13-14-15						130 psia	20 psia				
• V41P1700A (P) • LH_2 Ullage P1 • OFM 13-14-15						39 psia	32 psia			1490 1724 1726 1744 1746	

TABLE 8. – PMS MEASUREMENT REQUIREMENTS
(Continued)

SUBSYSTEM: Main Propulsion

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH	PRE—CONDITION TEST		F D A									
			SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION CHECK	SYSTEM STATUS LIGHT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW		
• V41P1701A (P) • LH_2 Ullage P2 • OFM 13-14-15						39 psia	32 psia			1490 1724 1726 1744 1746	
• V41P1702A (P) • LH_2 Ullage P3 • OFM 13-14-15						39 psia	32 psia			1490 1724 1726 1744 1746	
• V41P1490A (S) • GH_2 Press Disc • OFM 13-14-15						4500 psia	1500 psia			1416 1417 1160 1260 1360	
• T41X1724E (S) LH_2 Vent Valve • 1 Open • OFM 13-14-15											

TABLE 8. – PMS MEASUREMENT REQUIREMENTS
(Concluded)

SUBSYSTEM: Main Propulsion

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH	PRE—CONDITION TEST		F D A									
			SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION CHECK	SYSTEM STATUS LIGHT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW		
• T41X1726E (S) • LH_2 Vent Valve • 1 Open • OFM 13-14-15											
• T41X1744E (S) • LH_2 Vent Valve • 2 Closed • OFM 13-14-15											
• V41P1100C (P) • E1 LH_2 Eng. • Inlet Press						130 psia	20 psia			1434	
• V41P1200C (P) • E2 LH_2 Eng. Inlet Press • OFM 14						130 psia	20 psia			1434	
• V41P1300C (P) • E3 LH_2 Eng. Inlet Press • OFM 15						130 psia	20 psia			1434	

6.0 TYPICAL MONITORING SEQUENCE

Figures 9 and 10 show a typical type of monitoring sequence required for different mission phases.

Figure 11 demonstrates the type of parameter versus time monitoring that will be required.

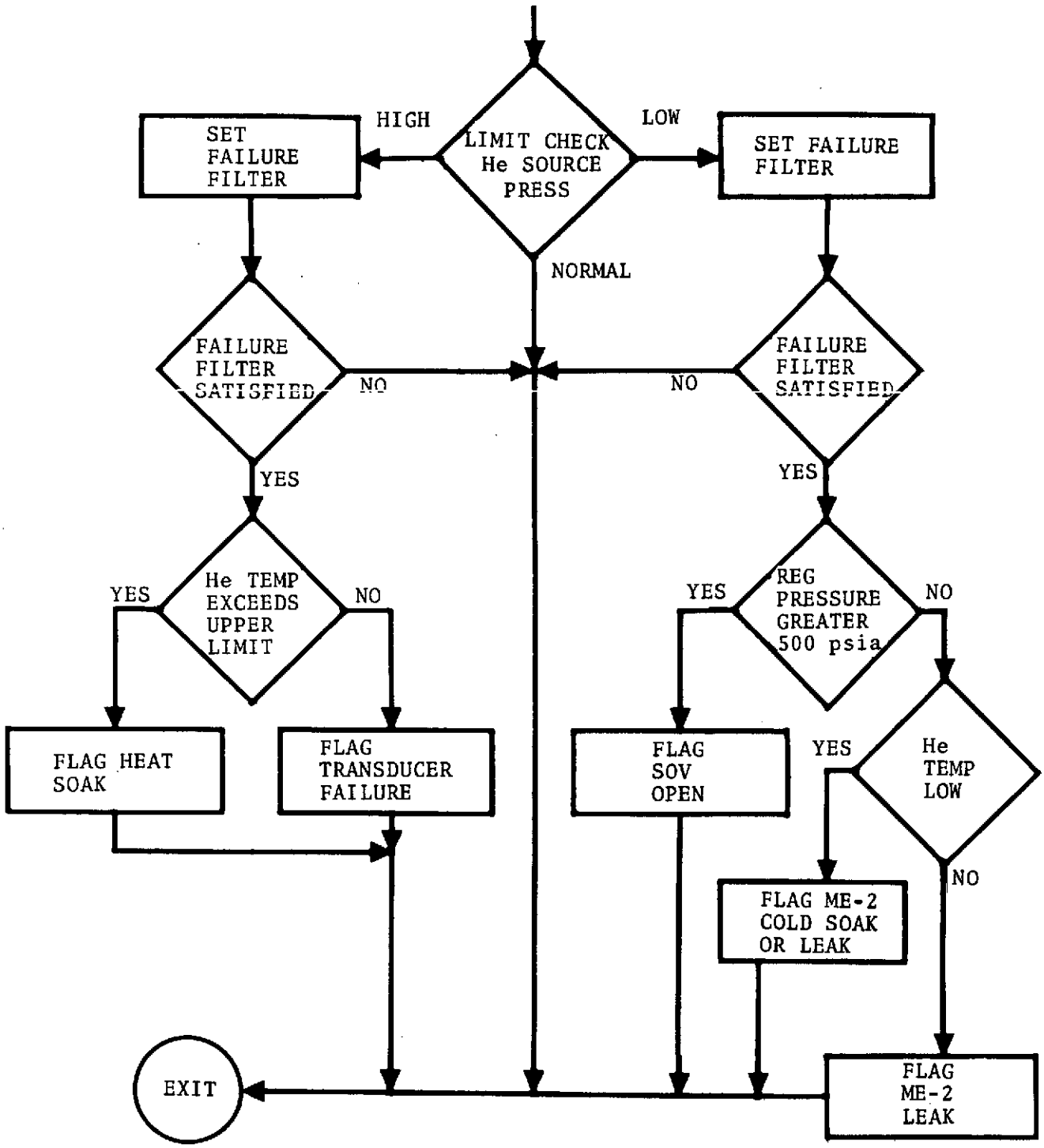

Figure 9. — Typical preburn He monitor enter from precondition.

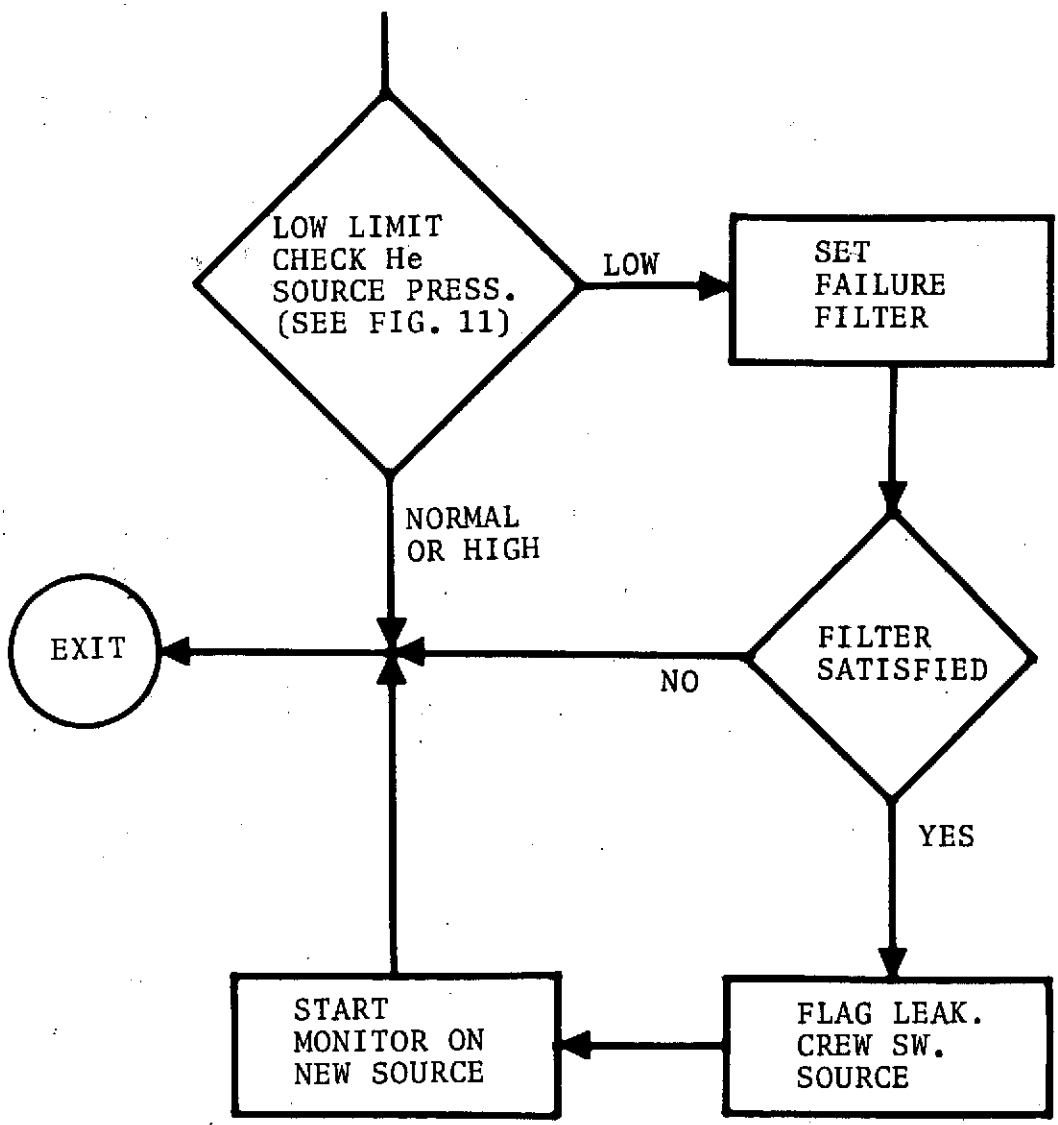

Figure 10. – Typical burn He monitor enter from precondition.

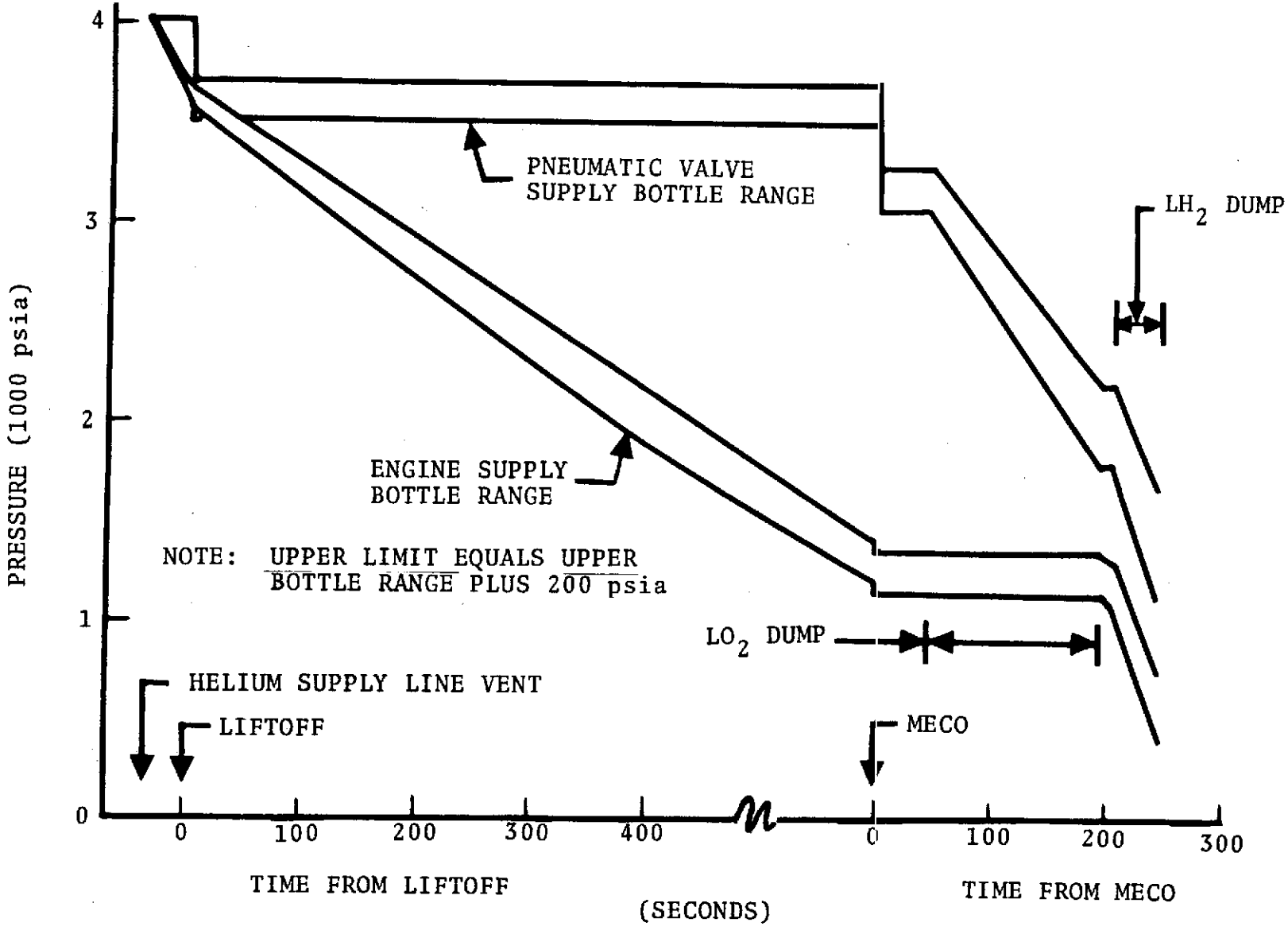

Figure 11. – Typical pneumatic system storage bottle pressure histories.

7.0 CONCLUSIONS AND RECOMMENDATIONS

The Master Measurements List, dated November 16, 1973, is not adequate for Main Propulsion Fault Detection and Annunciation.

The following measurements from the Operational Flight Instrumentation List, presented at the November 28 main propulsion panel meeting, should be added to the Master Measurements List, for the fault detection and annunciation:

V41X1517X	GO_2 Press Disc Valve Closed
V41X1774E	LO_2 Vent Valve 1 Closed
V41X1776E	LO_2 Vent Valve 1 Open
V41X1778E	LO_2 Vent Valve 2 Closed
V41X1780E	LO_2 Vent Valve 2 Open
V41T1161A	E_1 GH_2 Outlet Temp.
V41T1261A	E_2 GH_2 Outlet Temp.
V41T1361A	E_3 GH_2 Outlet Temp.
V41P1160A	E_1 GH_2 Outlet Press
V41P1260A	E_2 GH_2 Outlet Press
V41P1360A	E_3 GH_2 Outlet Press
T41X1724E	LH_2 Vent Valve 1 Closed
T41X1126E	LH_2 Vent Valve 1 Open
T41X1744E	LH_2 Vent Valve 2 Closed
T41X1746E	LH_2 Vent Valve 2 Open
V41X1417E	GH_2 Press Disc Valve Closed
No Assign Number	Eng. Comp. Amb. Temp. 1
No Assign Number	Eng. Comp. Amb. Temp. 2

All Measurements identified for fault detection and annunciation, in this document, should be made available to Performance Monitor.

In addition it is recommended that the controller data word list be revised. The 16 data words identified in table 5 should be included in the first 32 controller data words since only the first 32 words are available to Performance Monitor.

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